THE PRINCIPLES UNDERLYING FORCE-LIMITED VIBRATION TESTING USING THE FREQUENCY-SHIFT METHOD

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ABSTRACT. The traditional vibration test methodology of controlling the interface environment only to a motion based specification is often too conservative, inducing potentially excessive vibration responses at hardware resonant frequencies. This overtesting problem occurs because the smooth, input acceleration specification used in the test configuration is characteristic of a rigid, infinite impedance equipment mount; and not characteristic of the compliant, finite impedance equipment mount more typical of the service configuration. Recently, the so called dual controlled vibration test has emerged as a successful solution for ameliorating overtest conditions on a wide variety of hardware. In this technique, the interface environment is controlled to whichever interface parameter, force or acceleration, first reaches its control limit.

The salient principles underlying the force control methodology known as the *frequency-shift method* are analyzed. In this methodology, the force control spectrum is derived from the product of the envelope of the interface acceleration spectrum and the load dynamic mass evaluated at the resonant frequencies of the coupled source-load system. The source-load vibratory system is analyzed using the modal- and residual-mass two degree-of-freedom model. Under this model, the source and load masses are no longer idealized as lumped masses, but instead treated more realistically as distributed masses. Effective modal and residual mass concepts are introduced that permit both the source and load distributed masses to be modeled as discrete modal and residual masses connected at a common interface. The extremal, normalized force limits are then found for a given effective mass parameter set by tuning the natural frequency of the source and load modal oscillators to yield the maximum interface force. The absolute force limits can then determined from the normalized force limits given knowledge of the interface acceleration and load static mass.

To illustrate this methodology, case studies involving force-limited, random vibration testing of Cassini spacecraft hardware are presented. The effects of force-limiting on hardware responses are examined, and theoretical force limits are compared with their experimentally measured counterparts.

REFERENCES.

1. Murfin, W. B. 1968. Dual specification in vibration testing. *Shock and Vibration Bulletin*, no. 38, pt. 1 (August):109–113.

2. Salter, J. P. 1964. Taming the general-purpose vibration test. *Shock and Vibration Bulletin*, no.33, pt. 3 (March):211–217.

3. Scharton, T. D. 1994. Vibration test force limits derived from frequency shift method.*Jet Propulsion Laboratory* (Pasadena, CA), rept. JPL D-11455.

4. Scharton, T. D. 1995. Vibration-test force limits derived from frequency-shift method. *AIAA Journal of Spacecraft and Rockets* 32(2):312–316.

5. Smallwood, D. O. 1990. Development of the force envelope for an acceleration/force controlled vibration test. *Proceedings of the 61st Shock and Vibration Symposium* (October) 1:95–104, Pasadena.